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Humans to Mars: Logical Step or Dangerous Distraction?

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This paper examines post-Apollo proposals for human exploration of Mars and assesses their failure to win enduring political and public support. There are lessons to be learned that are applicable to current exploration efforts. Foremost among these is that the path to solar system exploration that has dominated the space community's thinking since the 1950s may not be a logical or politically feasible approach for the 21st century. The paper proposes that human exploration of the Moon and Mars should be decoupled and treated as separate ventures with each justified by its own merits and pursued at its own pace.

I. Introduction

Journeys to the Moon and Mars are linked in current planning and public perceptions of the future of human spaceflight. Going to the Moon and then to Mars has been represented as the logical sequence for space exploration efforts for more than five decades. But given what we've learned since the beginning of the space age, and our numerous experiences in which humans-to-Mars proposals have failed to win adequate support, is it time to reexamine, and perhaps sever, the Moon-Mars link? Have attempts to aim for Mars backfired, slowing or even reversing progress in civil space policies and goals? Is this happening today?

II. Repeated Attempts at the Von Braun Paradigm

The fascination with journeys to Mars goes back a long way, but it wasn't until the early 1950s that a technically grounded, well-thought-out plan for the endeavor emerged. Widely publicized in print media[1] and television[2] by Wernher von Braun and other prominent advocates, the steps in the plan were as follows:

1. Launch and operate Earth-orbiting satellites to learn about the technology and the space environment.
2. Conduct Earth-orbiting flights with human crews to learn how to live and work in space.
3. Develop reusable spacecraft to shuttle back and forth to low Earth orbit.
4. Build permanently inhabited space stations to observe Earth and serve as a launching point to other destinations in space.
5. Explore and settle the Moon.
6. Explore and settle Mars.[3]

Project Apollo, driven by national security and foreign policy concerns, diverged from the Von Braun paradigm by skipping steps 3 and 4 and aiming straight for the Moon. But once Apollo was on track to achieve its goals, NASA sought to return to the Von Braun path by going back to steps 3 and 4, directing its resources toward a reusable shuttle and a permanently manned space station. At the time, it was not expected that the U.S. space program would dwell on these tasks for over three decades before moving on to step 5, exploring the Moon. However, policy-makers at the end of the Apollo era, and for most of the time since then, were not inclined to support fast-paced shuttle and space station development, and were even less eager to endorse lunar exploration or human missions to Mars.

A. The Space Task Group

In February 1969, with the first Apollo Moon landing on the immediate horizon, President Richard Nixon appointed an advisory committee called the Space Task Group, chaired by Vice President Spiro Agnew,† to make recommendations for a post-Apollo space program. NASA's recommendations to the group[4] demonstrated ambitions beyond the shuttle and space station. Other human spaceflight programs on the space agency's wish list

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† The committee's members were Robert Seamans, Secretary of the Air Force; Thomas Paine, Administrator of NASA; and Lee DuBridge, Science Advisor to the President. Also participating were observers from the Department of State, the Atomic Energy Commission, and the Bureau of the Budget.

included a lunar-orbiting station and a Moon base, to be developed concurrently with a mission to Mars that would have flown to the red planet, under the "maximum rate" scenario, in 1981. Even under the slower-paced scenarios in the report, human crews would have been on their way to Mars by the end of the 1980s.

The Space Task Group's final report[5] did not wholeheartedly endorse NASA's high-tempo plans for human spaceflight. The general recommendations included the following:

- Apply space technology to the direct benefit of mankind.
- Operate military space systems to enhance national defense.
- Explore the solar system and beyond.
- Emphasize commonality, reusability, and economy.
- Engage broad international participation.

The Space Task Group also encouraged definitive responses to any future actions of the Soviet Union's space program, whether that be in the form of head-to-head competition or, under appropriate circumstances, cooperation on long-term space projects. For human planetary exploration, the report suggested a long-range goal of a manned Mars mission before the end of the 20th century. Even this less-ambitious timeline for visiting Mars fell on deaf ears among policy-makers for a variety of political and budgetary reasons, causing the Von Braun paradigm to unfold in slow motion over the next three decades.

Attempts to revive the Moon-Mars plan did not end there, however. The early 1980s brought the first flights of the space shuttle and the initiation of the space station program, paving the way for the next steps in the Von Braun path. Starting in the mid-80s, the president, the Congress, and a series of high-profile study panels weighed in on these next steps. Each time, the proposed visions of future human spaceflight gained no traction, with the possible exception of the current effort that began in 2004. A review of these activities is instructive, starting with the work of the study panels.

B. The National Commission on Space (NCOS)

The NCOS was a presidential commission mandated by the Congress. It began its work in 1985, headed by Thomas Paine, the former NASA Administrator who had been a member of the Space Task Group and an advocate of Mars exploration. The task assigned to the NCOS was to construct a U.S. civil space strategy for the next 50 years (i.e., through 2035). The Commission's mid-1986 report[6] outlined major steps in infrastructure development and recommended concurrent efforts in the civil and commercial sectors costing a percentage of the Gross National Product equal to less than half the peak Apollo rate, assuming annual GNP growth of 2.4% for the 50-year period, and assuming that commitment could be maintained for that long.[7] The three "mutually-supportive thrusts" of the Commission's proposed space agenda were:

- Advancing our understanding of our planet, our Solar System, and the Universe;
- Exploring, prospecting, and settling the Solar System; and
- Stimulating space enterprises for the direct benefit of the people of Earth.[8]

Mars was an integral part of the Commission's solar system plan. The report displayed a timeline with milestones that included a "human outpost" in 2015, "initial base" around 2022, and "full base" by around 2027.[9] Beyond the pure science aspects of Mars exploration, which contributed to the first two thrusts, there was no discussion of how Mars settlement would bring benefits to Earth. Mention of Mars was notably absent from the chapter "Space Enterprise," which addressed commercial development that would be the lynchpin of ongoing space activity.

Also notably absent was any follow-up to the Commission's space exploration recommendations by the Ronald Reagan Administration. It has been suggested that the White House staff deliberately shelved the report,[10] which came out at around the same time as the Rogers Commission report on the *Challenger* accident. The Administration's next (and last) policy directive addressing the civil space program[11] came more than a year and a half later, and contained only one paragraph on human exploration beyond Earth orbit. Neither the Moon nor Mars was mentioned. While the Administration's 1988 space policy recognized that there should be a "long-range goal of expanding human presence and activity beyond Earth orbit into the solar system," it put off any serious commitment by simply directing NASA to "begin the systematic development of technologies necessary to enable and support a range of future manned missions." Such development would be "oriented toward a Presidential decision on a focused program of manned exploration of the solar system."

Despite being rejected once again by top-level decision-makers, the human exploration of Mars would continue to be a key element in the high-visibility studies that followed, and would soon become a component of President George H.W. Bush's Space Exploration Initiative (SEI). (Further discussion of SEI is presented below.)

C. The Ride Report

In response to the NCOS and Rogers Commission reports, an internal NASA task group chaired by astronaut Sally Ride assessed possible future directions for the civil space program. The task group's August 1987 report, "Leadership and America's Future in Space," operated under a specific set of ground rules, two of which are of particular interest to this discussion:

- The initiatives [described in the report] should be considered *in addition* to currently planned NASA programs. They were not judged against, nor would they supplant, existing programs. [Emphasis in original]
- The Humans to Mars initiative should be assumed to be an American venture. It was beyond the scope of this work to consider joint U.S./Soviet human exploration.[12]

These ground rules tell us something about the direction handed down to the team by the NASA Administrator, James Fletcher. First, NASA clearly had no intention of sacrificing the space station to leap ahead in the Von Braun sequence. Second, there was a going-in assumption that there would be a Humans to Mars initiative.

Humans to Mars was the last of four proposed initiatives, the other three being Mission to Planet Earth (Earth science), Exploration of the Solar System (in this case referring only to robotic exploration) and Outpost on the Moon. The report gives some detail on initial Mars mission architectures, with three sortie missions beginning as early as 2005 followed immediately by a decision on a permanent Mars outpost. There is no discussion of the rationale for going to Mars aside from the oft-repeated notions of national pride and prestige and pursuit of scientific knowledge.

In its evaluation of Humans to Mars, the report notes that the initiative's requirements could overwhelm the space shuttle and space station, and would require an approximate tripling of NASA's budget in the mid-1990s. Reacting to the findings of the Rogers Commission, the report warns of the potential hazards of pushing the schedule too aggressively. It also acknowledges the NCOS finding that the public does not want another one-shot political stunt as the goal of the nation's civil space effort. The report concludes that:

> Settling Mars should be our eventual goal, but it should not be our next goal. Sending people to and from Mars is not the only issue involved. Understanding the requirements and implications of building and sustaining a permanent base on another world is equally important. We should adopt a strategy of natural progression which leads, step by step, in an orderly, unhurried way, inexorably toward Mars.[13]

The NASA Office of Exploration that was spawned by the efforts of the Ride task group issued its first annual report in November 1988, delving further into case studies for lunar and Mars exploration.[14] Using timelines similar to those in the Ride report, it looked at questions such as whether the Moon is an essential stepping-stone to Mars, and whether it would make sense to send humans to the Martian moon Phobos before sending them to the surface of the planet. There was no further examination of the justification for Mars exploration, simply a reiteration of the Ride report's views on national pride (including the inspiration of youth) and scientific advancement. Eight months later, the Space Exploration Initiative was introduced to take us back to the Moon and on to Mars.

D. The Augustine Report

A year after the Space Exploration Initiative was inaugurated by President George H.W. Bush, the Advisory Committee on the Future of the U.S. Space Program (the Augustine panel, named after its chairman Norm Augustine) was chartered to advise the NASA Administrator on alternative approaches to management and programmatic issues affecting NASA's future, and was directed to complete its study in just 120 days.[15] The Committee's recommendation regarding human space exploration, which it labeled Mission from Planet Earth, was for a "long-term goal of human exploration of Mars, preceded by a modified Space Station which emphasizes life sciences, an exploration base on the Moon, and robotic precursors to Mars."[16] This sounds remarkably similar to the program announced in January 2004 by President George W. Bush, with one important difference: the Augustine panel recommended annual budget increases for NASA of 10% per year for a decade. Then as now, the Congress was not inclined to give NASA increases of such magnitude – and for his 2004 exploration proposal, the younger President Bush was not inclined to ask.

The Executive Summary of the Augustine report[17] contains more discussion of the rationale for human and robotic spaceflight than many comparable space vision studies. It recognizes that Americans generally agree the nation should have a space program, but have a wide range of views on the appropriate content of that program. The Committee felt it would be a disservice to lay out an ambitious, accelerated plan in the absence of fiscal and technical realism.

Despite its endorsement of a humans-to-Mars goal, the Committee stated that "the space science program warrants highest priority for funding. It, in our judgment, ranks above space stations, aerospace planes, manned missions to the planets, and many other major pursuits which often receive greater visibility." The Executive

Summary goes on the say that "NASA has a number of other responsibilities to which it must attend. Foremost among these is the continued support of a strong aeronautics program." Given these views on NASA's priorities and the importance of a balanced program approach, combined with the Committee's concern that NASA was not receiving resources adequate to fulfill its program obligations, it is clear that human missions to Mars received at best lukewarm support from the panel. In a mild rebuff to the elder Bush Administration's SEI plans for a Mars mission by 2019, the Committee recommended that "the Mission from Planet Earth be configured to an open-ended schedule, tailored to match the availability of funds."[18] This weak endorsement echoes the Ride report, giving the impression that both of these studies included a Mars goal more out of habit than conviction.

E. The Synthesis Group

The Synthesis Group was formed by Vice President Dan Quayle, head of the National Space Council, in the aftermath of a 90-day NASA study delivered in November 1989 that was intended to supply the initial conceptualization of President Bush's Space Exploration Initiative.[19] The White House was dissatisfied with NASA's plan and sought wider participation in envisioning the ambitious programs.[20] The Vice President was interested in faster, more cost-effective methods of performing the missions. The Synthesis Group became the clearinghouse for suggestions from around the community on technical approaches to the overall program. As in the Ride report, four scenarios (referred to as "architectures") were presented. But unlike Ride's approach, all four described different ways of conducting human missions to the Moon and Mars, in keeping with the concept of the fledgling SEI program.

The Group's 1991 report[21] set the first piloted mission to Mars in 2014 in Architectures I, II, and III, and in 2016 in Architecture IV. But lackluster congressional support for SEI at a time of rising budget deficits ended the initiative over the next two years, rendering the Synthesis Group recommendations moot.

The Group did not attempt to estimate how much any of this would cost. However, two questions important to this discussion that they did address were "Why Mars?" and "Why now?" Unfortunately, the answers to both of these questions were unsatisfying. The two-paragraph justification for going to Mars centered on the fact that Mars is the most Earth-like of the other planets in the solar system and it would be interesting to study its geology and atmosphere, as well as look for evidence of past life forms.[22] While this is scientifically intriguing, from a practical and political perspective it ignores costs, risks, and the trade-offs of doing the same studies with increasingly sophisticated robots. As for why to do it now, the report falls back on familiar statements about national pride, our destiny to explore, and the derived benefits of advances in science and technology.[23] A thorough, clear analysis of how space exploration and development can serve national and global interests is absent.

F. Meanwhile, on Capitol Hill: The Space Settlement Act of 1988

As executive branch commissions contemplated the future of the civil space program prior to the start of SEI, some members of Congress grew impatient with the lack of presidential initiative in space policy. Led by Rep. George Brown (D-CA) in 1988, they made an attempt to chart the program's future course. Responding to a recurring theme in the reports of the National Commission on Space and the Ride panel, Brown submitted legislation called the Space Settlement Act, which declared that "the extension of human life beyond Earth's atmosphere, leading ultimately to the establishment of space settlements, will fulfill the purposes of advancing science, exploration, and development and will enhance the general welfare."[24] The Act also mandated that NASA prepare a biennial report for the president and Congress regarding progress toward space settlement goals, identification of requirements, and assessment of relevant economic and sociological factors.

The Space Settlement Act was passed as part of NASA's fiscal year 1989 authorization bill, and President Reagan signed it into law on November 17, 1988. However, aside from the reporting requirement, the Act's language was neither specific nor directive, so it never had any substantive influence over NASA's planning. The space agency's Office of Exploration, expected to implement the Act's reporting requirements, disappeared shortly thereafter and a similarly chartered office remained absent from the scene for over a decade. The biennial reporting requirement was discontinued in 1994 due to its lack of relevance to the political environment,[25] and was formally terminated by subsequent legislation[26] effective May 15, 2000. The language that remains in the statute provides no real guidance, merely stating that exploration leading to space settlements is a good thing for the nation. No specific goals, missions, destinations, or timetables are mentioned.

G. Long-Awaited Direction: The Space Exploration Initiative

George H.W. Bush used his speech at a ceremony honoring the twentieth anniversary of Apollo 11 to announce the Space Exploration Initiative, which featured a return to the Moon and a human expedition to Mars by early in the 21st century.[27] He backed it up with sizable requests for start-up funding, and had Vice President Dan Quayle and the

National Space Council devote the bulk of their efforts to promoting the concept. The idea was poorly received in Congress, which granted only token appropriations for preliminary studies. Even that meager funding dried up by 1993.[28]

The primary reason for the failure of SEI was that virtually no one outside the immediate benefactors in the space community was willing to commit to a decades-long project of this magnitude in a budget climate characterized by record deficits. The NASA 90-day study, mentioned earlier, followed up on the president's announcement with a long wish-list of programs that had been waiting for a window of opportunity for many years. But NASA managers misjudged how much the window had opened. Thirty-year cost projections in the range of $300 billion to $400 billion were more than the Congress was willing to accept. SEI, intended to be a bold vision, turned into an embarrassment for the president.

Negative reaction to the long-term cost of the project was only part of the reason why SEI was short-lived. The president's enthusiasm may not have been as deep as his Apollo anniversary speech seemed to indicate. After the initial rhetoric and start-up budget requests, he never again intervened on behalf of the program. Even if his conviction was strong at the beginning, he may have decided, after digesting the unfavorable initial reviews from Congress and the public, that it wasn't worth investing political capital in something which may not show results for 30 years.

The work of promoting SEI was left to the National Space Council, but its actions proved to be divisive rather than unifying. The Council's immediate rejection of NASA's 90-day study, and its initiation of the Synthesis Group effort to solicit cheaper alternatives from outside the space agency, alienated some inside the agency. NASA Administrator Richard Truly, who wanted the agency to stay focused on the shuttle and space station, openly expressed his disdain for SEI, further complicating the relationship with the Council. This friction between Truly and the Council contributed to Truly's departure as Administrator in early 1992.

The Council's relationship with Congress was frosty as well. More precisely, the Council's staff and congressional staffers were not communicating very well, much less cooperating. Concerned congress-members came to view the Council, which the legislature had eagerly endorsed just a short time earlier, as a means of wresting control of space policy from the Congress and NASA and consolidating it in the White House. Members began to call for more access to the inner workings of the Council and Senate confirmation of its executive secretary.[29] These dysfunctional relationships were counterproductive, undermining the support coalition needed for the program to succeed.

SEI's Moon-Mars plan proved to be a hard sell throughout its short life. No strategically significant rationale was articulated to justify the project's cost and risk. In his Apollo anniversary speech, and in a commencement address several months later,[30] President Bush used the familiar rhetoric of discovery, destiny, inspiration, national prestige, and investment in the future. This type of language was sufficient at the height of the Cold War to justify Project Apollo, but by 1989 policy-makers and the public were already looking for more. What assets and/or capabilities does this bring to us that we wouldn't have had otherwise? Are those benefits worth the cost and risk? What are the opportunity costs of not investing the resources elsewhere?

SEI, like Apollo, was a destination-based human spaceflight program that never got to the point of establishing a permanent exploration agenda. Unlike Apollo, it generated disinterested or negative reactions throughout the Congress, the media, and the public. Stakeholders persisted in asking, "Why do this?" or at least "Why do this *now*?" NASA and the Administration provided no answers that satisfied a sufficient coalition of decision-makers and the public.

H. Space Exploration Policy, 21st Century Style

The most recent incarnation of a Moon-Mars plan came from President George W. Bush in January 2004.[31] One of the objectives of the so-called "Vision for Space Exploration" is to "Extend human presence across the solar system, starting with a human return to the Moon by the year 2020, in preparation for human exploration of Mars and other destinations." Lunar exploration is treated as an enabler of "sustained human space exploration of Mars and other destinations." Although no target date is set for human trips to Mars, the policy states that the U.S. will "Conduct human expeditions to Mars after acquiring adequate knowledge about the planet using robotic missions and after successfully demonstrating sustained human exploration missions to the Moon."

Like the Space Task Group and SEI efforts, this is another attempt to resurrect the Von Braun paradigm – in other words, this "vision" is a half-century old. But there is an important difference that puts this program back in the Apollo mold: it skips the shuttle and space station steps. Despite having spent more than 30 years building and operating these two systems, the Bush policy directs that we discard them – as we did the Apollo hardware – rather than use them to launch exploration beyond low Earth orbit. What Von Braun saw as essential infrastructure for the exploration and development of space, current policy treats as an expensive distraction.

The current exploration plan shares a key deficiency with SEI: no strategically significant rationale has been articulated that justifies the cost and risk. NASA has undertaken a substantial effort to define the array of tasks that will be accomplished when we return to the Moon,[32] but no comparable effort can be performed for Mars at this time other than for pure science investigations. The space exploration policy provides no enlightenment in this area. Aside from the obvious scientific interest, the policy invokes the spin-off rationale, stating that "The new technologies required for further space exploration also will improve the Nation's other space activities and may provide applications that could be used to address problems on Earth... we cannot today identify all that we will gain from space exploration; we are confident, nonetheless, that the eventual return will be great." The challenge will be to convince policy-makers and the public that the return will be great enough to justify the cost and risk of sending humans to Mars.

I. Authorizing Exploration

The Congress seems to have been convinced that planetary exploration is worth some initial investment. The NASA Authorization Act of 2005 directs that "The Administrator shall establish a program to develop a sustained human presence on the Moon, including a robust precursor program, to promote exploration, science, commerce, and United States preeminence in space, and as a stepping-stone to future exploration of Mars and other destinations."[33] Enthusiasm for Mars is tempered by realism, however. The related milestone specified in the statute calls for "Enabling humans to land on and return from Mars and other destinations on a timetable that is technically and fiscally possible."[34] Later in the text, the NASA Administrator is directed to "construct an architecture and implementation plan for NASA's human exploration program that is not critically dependent on the achievement of milestones by fixed dates."[35] Such language is clearly intended to ensure that NASA's exploration preparations are modest in cost and are reversible.

The NASA Authorization Act of 2005 and the annual NASA appropriations bills since 2004 have been touted as evidence that the legislature – and by extension, the American people – fully support the entire exploration package as promulgated by President Bush in January 2004. However, dispassionate examination of the 2005 authorization language and the dollars in the spending bills reveals that the only thing the Congress has fully embraced is a replacement for the space shuttle that is cheaper to operate. Some funding has been provided to test the waters on lunar exploration and development, but the real costs of that endeavor won't appear until sometime next decade. At that point, if the Moon is still being portrayed by many in the community as merely a stepping-stone to Mars, legislators will be asking themselves, "If we buy into the Moon program, are we also buying into Mars? Do we really want to do that?"

J. Back to Von Braun?

We seem to be getting back on track with the Von Braun paradigm – sort of. Clearly, Wernher von Braun did not envision going backwards a generation in spacecraft design once a reusable Earth-to-orbit shuttle had been developed, nor would he agree with bypassing the space station on our way to deep space. But today, we are targeting the same destinations in the same sequence, and like the famed German engineer, we are devoting far more attention to how and when we will do it than on why.

III. Do We Know Why We Should Go to Mars?

According to the advocacy group The Mars Society, "We're ready. Though Mars is distant, we are far better prepared today to send humans to Mars than we were to travel to the Moon at the commencement of the space age. Given the will, we could have our first teams on Mars within a decade... No nobler cause has ever been."[36] The Mars Society's assertion about our readiness level for the journey is debatable, but the group's enthusiasm is undeniable. In general, Mars advocates can come up with a list of reasons for sending humans to Mars, but to date none of these reasons can satisfactorily answer concerns about the cost, the risk, and the urgency.

A. Comparing Rationales

The rationale for going to Mars can be assessed in terms of accepted justifications for spaceflight in general. As expressed by Dr. Roger Launius, space historian at the Smithsonian National Air & Space Museum, they are:

- Scientific Discovery and Understanding
- National Security
- Economic Competitiveness
- Human Destiny/Survival of the Species

- National Prestige/Geopolitics[37]

Using a planning horizon that runs through mid-century, we can eliminate national security as a rationale for going to Mars. The U.S. currently has a substantial national security space program that has no foreseeable requirement for people in deep space. Someday, as we prepare for planetary defense, there will be a requirement for interception of asteroids headed for Earth (or one of our space settlements). Diversion or destruction of such an asteroid is preferably done as far from Earth as possible using either manned or automated spacecraft. In any case, this scenario is beyond the capabilities we will have in the next few decades, so it doesn't apply to our consideration of current exploration plans. Therefore, a national security rationale for humans on Mars is several decades premature.

The same is true for the economic competitiveness rationale. For the foreseeable future, our space capabilities are far too underdeveloped to produce direct benefits to the Earth-based economy from Mars – marketable materials, energy, or unique products and services – so the only plausible economic benefit is technology spin-offs. However, spin-offs are, by definition, secondary benefits and therefore not a sufficient justification for a space exploration program. An investment of this magnitude must be based on its primary benefits. While high-tech spin-offs have brought benefits to society and boosted the U.S. economy, the value of such benefits is impossible to measure with any precision. Additionally, the technology investment picture in the U.S. has changed considerably since the Apollo era. Computer hardware and software, telecommunications networks, medical technologies, and most other engineering advances are now being driven by private sector and non-space government investment. Starting in the 1980s, U.S. industry surpassed the government in research and development spending, so NASA technology investment today is going to have less of an impact than it once did in all but the most cutting-edge technologies. Furthermore, NASA will be even less likely to push the state of the art under a continued policy of maintaining nearly flat budgets and relying heavily on existing technology.

The human destiny/survival of the species rationale covers a variety of concepts, including the planetary defense scenario mentioned earlier. It could be argued that this is not only a primary rationale, but *the* primary rationale. The drive to explore space to continue the evolution of our society and help insure us against devastating events that could befall Earth is powerful and worthy of long-term consideration. But as discussed, it will be many decades before we can do anything about it. We have yet to learn how to live, work, and build infrastructure and communities away from Earth. Our challenge at this stage is to go through that learning process, the pace of which is impossible to predict.

The national prestige/geopolitics rationale is always present at some level for all nations embarking on space exploration and development programs. But the geopolitical environment is far different than it was 40 years ago in the midst of the Cold War. The gains to be obtained by any one nation from space spectaculars are greatly diminished. Instead of a bipolar competition, today we have a growing number of countries capable of showing off their space achievements, lessening the impact of what any one country does alone and increasing the likelihood that noteworthy efforts will be multinational. At the same time, world opinion regarding the U.S. has declined in recent years. If the U.S. puts forth an image of "sole superpower" aided by nationalistic space achievements, many around the world will see this as clashing with the political, economic, and technological leveling effects of globalization that lead the rest of the world to view the concept of "superpower" as archaic. Similarly, anti-globalizers and nations unfriendly to the U.S. may view space spectaculars with distain, viewing them as attempts by the U.S. to flex its nationalistic muscles to the detriment of other nations. Therefore, it appears unlikely that exploration of Mars, no matter how successful, would win many hearts and minds around the world. Unless large-scale benefits to Earth (not just the U.S.) were clearly visible as a result of the program, the more likely response around the world would be, "They should have used the resources to [cure AIDS, end starvation in poor countries, *fill in your favorite world problem*]."

That leaves the scientific discovery and understanding rationale. Much has been said and written about the wealth of knowledge that the space program has brought to us about Earth and the rest of the universe. The past half-century has seen textbooks rewritten multiple times and the emergence and blossoming of new scientific disciplines. Arguments about NASA programs and funding have persisted regarding the right balance between human and robotic missions that will produce the most value for our science dollars. The question that needs to be addressed in current planning for human exploration is whether science is a primary or secondary goal. If it is a primary goal, there will be plenty of work for people to do on the Moon, but little or none to do elsewhere for a long time to come because sending robots will be a far more efficient use of resources. In other words, as the sophistication and productivity of robots improve, there is no scientific rationale for sending humans to Mars that justifies the added risk and expense. Having scientists working on site is the preferred approach when the cost-benefit analysis makes sense. It is reasonable to believe that this will be the case on the Moon in the foreseeable future, but we lack the knowledge and experience to make a credible estimate of when this will be true of Mars.

Alternatively, science may be a secondary goal in this venture. If that is the case, the argument for completely robotic investigation of Mars still dominates, and program advocates should not use science as a primary selling point. This does not imply that science conducted by humans on Mars isn't important. Rather, it is a recognition that humans still have a lot to learn in cislunar space – and perhaps on other near-Earth objects – before such work can be done at acceptable levels of risk and cost.

For those who are looking for spin-off benefits from Mars exploration, one of the most obvious and useful comes from unmanned missions. Robotics with increasingly sophisticated mechanical, sensor, and autonomous operation systems are needed to continue the evolution of these missions. Automated space probes, as much or more than human space missions, can drive application of this technology in physically demanding, remote, and hostile environments on Earth.

B. Considering Public Opinion

Public opinion polls on space typically hold few clues as to how funding should be allocated. Respondents are fairly evenly divided on the relative importance of human vs. robotic missions, but historically have preferred scientific return over space spectaculars like a piloted mission to Mars.[38] Robotic exploration of Mars appears to have gained favor as a direct result of rover operations, first with *Sojourner* in 1997 and more recently with *Spirit* and *Opportunity*.

In recent years, there have been public opinion polls specific to the exploration mission that reveal new and ominous signs to policy-makers and NASA. The most visible has been a series of polls commissioned from the Gallup organization by the Coalition for Space Exploration, an alliance of companies and professional organizations formed in 2004 to promote the exploration program.[39] Numerous press reports and NASA's website[40] have focused on the positive responses to the question: *If NASA's budget did not exceed one percent of the federal budget, to what extent would you support or oppose this new plan for space exploration? Would you strongly support it, support it, oppose it or strongly oppose it?* Jeff Carr, chairman of the Coalition, summed it up this way: "Cumulative results indicate that, over the course of time and despite varying world and national circumstances, the American people still strongly support space exploration and are willing to support its funding at current levels or even slightly increased."[41]

A closer look at the detailed results reveals a more nuanced and somewhat less optimistic interpretation. The three surveys were performed in June 2005, March 2006, and August 2006. Press coverage failed to note that between the first and last survey, there were significant negative changes in the results. Responses of "support" and "strongly support" dropped 11 points (from 77 to 66 percent) and responses of "oppose" and "strongly oppose" increased 8 points (from 20 to 28 percent). There were no questions specifically directed at assessing the level of support for human missions to Mars.

The Gallup surveys were broken down by age, gender, education, political identification, voter registration, and region. The results in each of these categories roughly paralleled those that have been seen over the past three decades. However, the long-duration support required to sustain exploration plans suggests that particular attention should be paid to younger age groups that will see exploration efforts develop throughout their careers and may have an outlook on human spaceflight different from those who lived through the Apollo era. Unfortunately, in each of the three surveys the youngest age group (18-34) constituted only 16 to 17 percent of the sample, the smallest of all the age groups. According to the information on sampling tolerances in the August 2006 Gallup report, this age group's results, considered separately, have a sampling error three to four times larger than the 3 percent error rate for the study's entire sample.

Another public opinion survey, by Dittmar Associates Inc.,[42] has garnered considerable attention in the space exploration community. Conducted in August through November 2004, it sought information on support for NASA and its exploration goals in general, but also dug deeper into issues such as human vs. robotic missions, the level of interest in human exploration of the Moon and Mars, the appropriate level of NASA funding, and the relevance of NASA to our daily lives. While the overall results of the study were positive for space exploration, it revealed some troubling signs when broken down by age group.

With the exception of robotic Mars missions, which received good support across all ages other than those over 75, the youngest age group showed little enthusiasm or interest in space exploration endeavors. The greatest concentration of support came from the baby boomers, who will reach retirement age in 2010-2029, precisely the time when the exploration effort needs sustained momentum.

The youngest age group in the Dittmar study, 18-24, presumably will pay for the exploration program with their tax dollars for the next 40 years. This age group includes those in college, graduate school, or just starting their careers. The Dittmar team was surprised that the primary response from this group was disinterest. The only thing that excited the members of this cohort was the robotic exploration of Mars.

Dittmar Associates did a follow-up study[43] in October 2005 through February 2006 with a larger, 18-24-only group to further investigate this surprise finding and make sure it wasn't just an artifact of sampling error. The results corroborated the findings of the original study and also yielded the following:

- 55% of respondents were aware of the exploration plan, but the typical extent of their knowledge was that it is "something about the Moon."
- 27% expressed doubts that NASA had gone to the Moon.
- 39% thought nothing useful has come out of NASA.
- 72% believed NASA money would be better spent elsewhere.

Mission-specific opinions included the following:

- 52% supported more rover/robot missions. There was particular interest in mission designs featuring tele-presence.
- Regarding return to the Moon, 23% identified themselves as "disinterested," 49% as "neutral," and only 29% as "interested."
- Regarding human missions to Mars, respondents were opposed by a ratio of three to one. Chief objections were that it's too difficult, too costly, and it seems pointless.

If the survey's results are an accurate indicator of what the future holds, the younger generation needs to become engaged and enthused about space in the next few years as they become politically active, or else the future does not bode well for sustained exploration.

Concerns about public opinion may become problematic even before young voters mature. A recent Harris poll on fixing the U.S. budget deficit held another ominous message for space exploration, with the potential for negative consequences in the near term. Among the questions in the March 2007 poll, respondents were asked to pick two federal programs (from a list of 12) that should be cut to reduce government spending. The space program was chosen by 51% of respondents, topping the list by a wide margin (13 percentage points above the second choice).[44] This result indicates that approximately half of the U.S. voting-age population views the civil space program as either a waste of resources or simply a non-essential activity. If other polling results, such as the Gallup surveys discussed earlier, accurately portray two-thirds of the population as supporters of space exploration, then a significant percentage of those supporters see the space program as a luxury item that could be sacrificed in a constrained budget environment.

IV. If Not Mars, Then What?

A. Breaking Out of the Von Braun Paradigm

Humankind's fascination with Mars has been with us for centuries, and for at least a half-century the conventional wisdom has been that Mars is the next logical destination for human spaceflight after the Moon. This becomes problematic when it is assumed that touching down on the Moon means setting sights on reaching Mars soon afterward, despite the far higher costs and degree of difficulty. Mars is not a second, slightly farther moon of Earth. There is no reason to expect that the long leap from the Moon to Mars will take place within one working lifetime. In a venture as expensive, risky, and significant as the ongoing exploration of the solar system, it is more important to get it right than to do it fast. Undue haste, in addition to endangering missions, also may prompt observers who are under 40 years old today to view the enterprise as a mid-life crisis project for baby boomers who are pining for the Apollo days. Under such circumstances, political support could evaporate for a generation or more, setting back spaceflight dreams rather than moving them forward.

Although we have increased our knowledge of the red planet tremendously through several successful robotic missions over the past 30 years, has this increased our skills and readiness sufficiently to support ongoing human operations there? Or has it simply awakened us to new challenges that must be addressed before we go, effectively pushing our departure date farther into the future? We know today that Apollo-era projections of Mars visits by the 1980s, as NASA proposed to the Space Task Group in 1969, were extremely naïve, both technically and politically. But recently, the NASA Administrator expressed confidence that we are on the threshold of undertaking this challenge:

> By the 2020's we will be well positioned to begin the Mars effort in earnest. The lunar campaign will have stabilized; a human-tended outpost will be well established; we will have extensive long-duration space experience in both zero- and low-gravity conditions, and it will be time to bundle these lessons and move on to Mars...[45]

This is an extraordinary statement. Despite nearly five decades of spaceflight efforts, we are still at a primitive stage in our attempts to conduct efficient, productive human operations in low Earth orbit. To think that in just twenty years we will have learned all the lessons needed to operate on a distant planet, two to three orders of magnitude

farther than the Moon, seems exceedingly optimistic. The bulk of this experience must come from spaceflight systems yet to be built, lunar architecture yet to be designed, and long-duration missions yet to be planned.

B. Making Space Relevant to Earth Priorities

When we begin human exploration of the Moon and development of cislunar space, our task will be to make this activity sustainable and valuable – objectives that will not be achieved by immediately turning our attention and resources toward Mars. Our two overarching tasks will be 1) learn to survive, work, build infrastructure, and form communities that produce value in excess of investment; and 2) direct efforts toward making profound, visible contributions to solutions for Earth's problems.

The first task is rather obvious – humanity must negotiate this learning curve if we are to go to Mars or anywhere else. The second task requires further discussion.

The list of the world's problems seems infinite judging from our daily exposure to various news outlets, offerings at the local bookstore, gossip around the water cooler, and the pontifications of barbers and cab drivers. The difficulty is determining which ones can be addressed by the exploration and development of space, and how this can be achieved. Fortunately, numerous global trend-watchers have published their observations and prognostications throughout the space age. A very small sample of them are highlighted here, followed by an analysis that links their recurring themes in ways that can help shape a space development plan that delivers broad benefits to Earth.

As the Apollo lunar missions were ending and environmental awareness was growing, the international think tank The Club of Rome released a study, conducted by a group at MIT, called "The Limits to Growth."[46] The report received wide notoriety, and much derision from some quarters, for what was seen as a doomsday prediction:

> If the present growth trends in world population, industrialization, pollution, food production, and resource depletion continue unchanged, the limits to growth on this planet will be reached sometime within the next one hundred years. The most probable result will be a rather sudden and uncontrollable decline in both population and industrial capacity.

Less well reported was the report's other conclusion, that it is possible to alter these trends.[47] For our purposes, the most important thing to take away from the report is the list of what were judged to be the five major trends of global concern: accelerating industrialization, rapid population growth, widespread malnutrition, depletion of nonrenewable resources, and a deteriorating environment. At least some of these are addressable, and are being addressed, by space capabilities. We'll return to this in a moment.

Moving ahead to 1993, Yale historian Paul Kennedy wrote *Preparing for the Twenty-First Century* in which he examined global problems and trends with an eye toward the interactions of circumstances that make societies collapse. As author of the best-selling *The Rise and Fall of the Great Powers*, Kennedy was well versed in how this had occurred historically. His list of troublesome and interrelated trends includes:

- Population explosion and changing demographics.
- Globalization of business driven by technological advances.
- Widespread environmental damage.
- Global warming.[48]

Kennedy was writing at a time when popular recognition of globalization was just beginning to emerge. He found it troublesome because he believed the interaction between growing population, job displacement, and illegal migration would widen the rift between rich and poor countries.

More recently, Thomas Homer-Dixon, a professor of political science at the University of Toronto, published *The Upside of Down: Catastrophe, Creativity, and the Renewal of Civilization*, which reads like a post-9/11 update to Kennedy's book. Homer-Dixon refers to the big global problems as tectonic stresses, and lists them as follows:

- Population stress arising from differences in the population growth rates between rich and poor societies, and from the spiraling growth of megacities in poor countries.
- Energy stress – above all from the increasing scarcity of conventional oil.
- Environmental stress from worsening damage to our land, water, forests, and fisheries.
- Climate stress from changes in the makeup of our atmosphere.
- Economic stress resulting from instabilities in the global economic system and ever-widening income gaps between rich and poor people.[49]

This small sample of the literature of recent decades is enough to show a consistent message: the planet suffers from environmental degradation, climate instability, current or anticipated scarcities of energy and raw materials (including food and water), and increasingly uneven distribution of wealth. These problems are rooted in excessive population and industrial growth.

There is another important commonality in the literature: the Earth is always treated as a closed system, with solar radiation being the only external input. For example, Homer-Dixon specifically points out that humanity "can't get its resources or expel its pollution beyond Earth's boundaries."[50]

Here is where we begin to see how space development can contribute to global solutions – if we can change the assumption that Earth is a closed system.

Currently, pessimists may view space technologies as part of the problem: communications satellites enable excessive growth and global reach for industries; national security satellites enhance military capabilities for powerful countries to the detriment of the less powerful; remote sensing satellites give an information advantage to wealthy, technically advanced nations over less-advanced nations having potentially valuable resources within their borders. In contrast, optimists see communications satellites as a way of bringing the world together in both good and bad times; national security satellites as tools for preventing conflict; and remote sensing satellites as essential instruments for disaster relief and for identifying and studying large-scale developments like climate change, pollution, deforestation, ozone depletion, and other potentially threatening conditions.

Today's space services – communications, navigation, and Earth observation – facilitate growth and enable the detection and analysis of regional and global-scale problems. But continued refinement of these three capabilities cannot be the only accomplishments expected of 21st century space development. New services that directly contribute to global solutions could and should be developed. In the words of Paul Kennedy, "it is not enough merely to understand what we are doing to our planet, as if we were observing the changes through a giant telescope on Mars."[51]

Population pressure will not be directly remedied by spaceflight advances in the next few decades. We are already at the stage where migration to off-world settlements would need to number in the tens of millions in order to provide any significant relief on Earth – obviously impractical for a long time to come. However, within this century humanity could make substantial contributions toward solving global problems if we persistently direct our attention and resources to doing so. Areas where we could see advances include:

- **Collection and distribution of energy**. The idea of gathering solar energy in space and beaming it to the terrestrial power grid has been around for four decades, spawning a variety of advanced design concepts and subsystem prototype demonstrations. Like communications signals, beamed energy is a weightless electromagnetic product that has near-universal demand on Earth. A concerted effort could make this energy source an important addition to the energy mix, supplanting some of the environmental impact of fossil fuel use. Other approaches that have been suggested include relay satellites to transmit power from point-to-point on Earth (allowing redirection of surpluses to areas in need), and mining of helium-3 on the Moon to power fusion reactors on Earth, should this method of power generation prove feasible.
- **Extraction and processing of raw materials**. The Moon and other near-Earth objects initially can provide materials for the continuing development of space infrastructure. Later, as space facilities and experience grow, the materials can be processed into a form useful on Earth. Lightweight, high-value products will dominate the early years of this activity, but eventually the increasing efficiency of space-to-Earth transfers may allow bulk products to be transported economically as well. The high point of this development will be the large-scale migration of heavy industry – both manufacturing and energy generation – into space. In addition to the availability of extraterrestrial materials, such industries will take advantage of new microgravity processes and easy access to solar energy and hard vacuum.
- **Routine construction and repair in space**. As cislunar space becomes more active, infrastructure elements will be built and repaired there, with only the highest-value components shipped up from Earth. A variety of plug-and-play platforms will provide affordable space services, and a used satellite market will develop.

Eventually Earth could see relief to the stresses that humanity has imposed on it. Earth would no longer be a closed system, thus overcoming our Malthusian dilemma. Land, air, and water could recover and be preserved through increased use of extraterrestrial resources that relieve the need for excessive ground-based extraction, transport, and processing. As land use patterns change, and space technology provides ubiquitous services (including top-quality education) that are not reliant on major population centers, the current incentive to abandon the countryside and flock to the cities will be reversed. Just as the automobile determined settlement patterns in the United States during the 20th century, space technology will be an integral driver of settlement patterns worldwide in the 21st century.

None of this will be accomplished by directing our attention and resources to human missions to Mars. Rather, a humans-to-Mars goal at this stage of our evolution would consume resources that could have been more productively applied to the development of cislunar space. Such development will allow us to choose a time for our first trips to Mars after we have the space infrastructure, experience, techniques for "living off the land," and

wisdom to know what to do with a community on Mars (other than basic science). When we go, we will be ready to establish a sustainable, productive settlement, based on what we learned in Earth's environs.

V. Conclusion

Mars is scientifically fascinating, but beyond that there will be insufficient rationale to send crews there for at least two generations. People eagerly support adventurers like mountaineer George Mallory who wanted to scale Mt. Everest "because it is there," but when the adventure is several orders of magnitude more risky and expensive and is being paid for by their tax dollars, they rightfully demand more substantial justification.

Numerous challenges face our planet in the coming decades. Among the most amenable to the application of space technology are environmental degradation and climate change. As these problems grow worse and public concern increases, the world will look to space technology and the nation will look to NASA for information and solutions. There will be an expectation that NASA has maintained its historic levels of activity and expertise in these areas. If that turns out not to be true, the perception will be that the agency has sacrificed down-to-Earth societal needs for the sake of Mars ambitions having questionable value. To make NASA's efforts more relevant to national needs, the Congress will be compelled to shift priority and funding to programs such as automated science missions and global climate studies, possibly displacing human spaceflight programs. If NASA is not given adequate resources to pursue both Earth science and human exploration, these circumstances could undermine both Mars exploration and the development of cislunar space for decades to come.

If lunar activity is depicted as solely or primarily directed at paving the way to Mars, and long-term commitment to Mars fails to materialize among policy-makers and the public, then neither endeavor will succeed and we will lose the momentum for beneficial development of space that could have been achieved by upcoming generations. We will be back where we are right now with no human activity beyond low Earth orbit – at least, no U.S. activity. Other nations may decide over the next two decades to keep their human spaceflight programs focused on cislunar space, and the U.S. could find itself on the sidelines, getting nostalgic about the space shuttle.

Human missions to the Moon and Mars are completely different ventures that need to be decoupled. The link between the two must be severed in planning for the nation's space program and in the minds of constituents. The Moon, and cislunar space in general, must be seen as worthy of exploration and development on their own merits. The Moon is not merely a stepping-stone to Mars. Rather, the Moon is a place to set up operations for the long haul to discover how to live there and do things of lasting importance, for the benefit of Earth and our long-term future in space.

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